Impact of pasteurisation and storage conditions on the physicochemical properties of acerola jelly

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Abstract:

Acerola, a fruit rich in bioactive compounds such as polyphenols and vitamin C, is highly susceptible to degradation under temperature influences. This study aimed to evaluate the impact of pasteurisation and storage conditions on the stability of these compounds in acerola jelly. Analytical findings revealed that thermal treatment at 80°C for 5 minutes effectively eradicated total aerobic bacteria and mould yeast content. Furthermore, this treatment preserved the vitamin C and phenolic content, as well as the sensory quality of the jelly, better than other samples. The study also discovered that during storage, the degradation of vitamin C and polyphenols in acerola jelly adhered to the first-order model and the Arrhenius model. In contrast, attributes such as total soluble solids (TSS), pH, and titratable acidity (TA) remained constant during pasteurisation and storage. Kinetic parameters, including D-value, k-value, z-value, and activation energy (E_a), indicated high stability of the product when stored at a low temperature of 4-6ºC. These findings suggest that acerola jelly has considerable potential for commercial production.

Keywords: **acerola jelly, pasteurisation, polyphenol, storage, vitamin C.**

Classification numbers: **2.2, 2.3**

1. Introduction

Acerola, renowned for its richness in bioactive compounds, possesses a vitamin C content notably higher (over ten times) than many other fruits, such as oranges,

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tangerines, and mangos. Besides vitamin C, acerola also encompasses an array of phenolic compounds, which include simple phenols, phenolic acids (derivatives of hydroxybenzoic and hydroxycinnamic acids), flavonoids, coumarins, stilbenes, and lignans [1]. Acerola extracts have been reported to exhibit robust antioxidant, anti-inflammatory, anti-hyperglycaemic, anti-tumour, anti-toxic, and hepatoprotective properties [2]. However, acerola fruits present several challenges, such as a succulent, thin peel, a soft texture, and a propensity to ripen rapidly, complicating distribution and storage. Consequently, various acerola-based food products, like powder, jam, and juice, have been the focus of several studies [3-5].

Acerola jelly, derived from acerola juice with added flavouring and stabilising agents, not only offers a pleasing taste but is also rich in vitamin C and polyphenols. Previous studies have indicated that the biological compounds in acerola products undergo changes during production, storage, and transportation. Such changes are predominantly due to undesirable reactions like oxidation and non-enzymatic browning, which occur continuously during storage and lead to the deterioration of the physicochemical properties of fruit products. These degradations are notably pronounced at elevated temperatures. Given these detrimental effects on nutritional composition and sensory quality, understanding the deterioration causes and identifying optimal storage conditions for food products is essential. However, reports on the stability of acerola jelly during processing, storage, and under varying temperature conditions are scarce. Hence, this study aims to evaluate the physicochemical property changes in acerola jelly under different thermal treatment and storage conditions.

2. Materials and methods

2.1. Materials

The chosen acerola fruits belonged to the Malpighia glabra variety, commonly known in Vietnam as Sơ ri chua or sour acerola. These fruits were sourced from a farm in Go Cong, Tien Giang province, Vietnam. Selection criteria included fruits that were ripe, red-orange in colour, and free from physical or microbiological damage (e.g., dark brown, bruised, surface mouldy, fermentable, or strange smells). Post-selection, the fruits were washed, drained, and stored at -18^{o}C until use.

The stabilising agent used was Aquagel WD-7183, procured from Marcel Carrageenan (Philippines). This additive, prevalent in fruit jelly product processing, consists of carrageenan, sodium dihydro citrate, konjac powder, and potassium chloride, as per supplier information.

2.2. Chemicals

Chemicals utilised in this study included ascorbic acid, gallic acid (Sigma Aldrich, Singapore), Folin-Ciocalteu (Merck, Germany), 99% methanol (Chemsol, Vietnam), hydrochloric acid (HCl), sodium chloride (NaCl), potassium iodide (KI), iodine (I_2), starch (Xilong, China), plate count agar (PCA), and potato dextrose agar (Himedia, India).

2.3. Experiment design

Effect of pasteurisation conditions: Thawed acerola fruits were processed using a kitchen juicer (HR 1863, Philips, China). The extracted juice was then blended with other ingredients, following the proportions outlined in Table 1. These proportions were based on preliminary survey results. The mixture underwent heating at 80^{o}C for 5 minutes to ensure complete dissolution of all ingredients. Subsequently, the hot sample solution was poured into aluminium luminate bags (6×11 cm), each containing 30 g of the mixture. The sealed bags were pasteurised using a retort (ALP Model MCY-40L, Japan) at various time intervals (5 and 10 minutes) and temperatures (80, 85, and 90^{o}C). Post-pasteurisation, the samples were cooled to room temperature in a water bath and then refrigerated for further analysis.

Table 1. Formulation of acerola jelly.

Material	Content (g)
Acerola juice	20.00
Sugar	19.57
Citric acid	0.23
Stabiliser agent (aquagel)	1.50
Water	58.70
Total	100.00

Effect of storage conditions: The samples were prepared identically to those in the initial experiment. They were then stored at three different temperatures: 8-10^{o}C in a refrigerator (Zanotti S.p.A., Italy), 29-31^{o}C (room temperature), and 40^{o}C in an

incubator (IN 110, Memmert, Germany). Every five days over a period of 30 days, the samples were assessed for their physicochemical properties.

2.4. Analytical method

Determination of TSS, pH and TA: The TSS content was measured using a refractometer (Atago, 0-32°Bx, Japan). Total acidity (TA) was determined by titration with 0.1 N NaOH using 1% phenolphthalein as an indicator [6]. The pH was recorded using a pH meter (Hanna 211, USA). Prior to these assessments, samples were macerated with distilled water.

Determination of total phenolic content (TPC): Following the extraction method described by G. Xu, et al. (2008) [7], the TPC was determined in accordance with Y.Y. Lim, et al. (2007) [8]. In this process, 0.3 ml of the diluted sample was mixed with 1.5 ml of 10% Folin-Ciocalteu reagent. The mixture was allowed to stand for five minutes before the addition of 1.2 ml of 7.5% Na_2CO_3. After thorough mixing, the mixture was left for 30 minutes at room temperature (29-31^{o}C). The analysis of optical density was then performed at 765 nm using a UV-vis spectrophotometer (UV-1800, Shimadzu, Japan), under dark conditions. TPC was calculated using Eq. (1) and expressed as mg gallic acid equivalents per 100 g dry matter (mg GAE/100 g dm):

$$\text{TPC} = \frac{(y-\text{b}) \times \text{V} \times \text{DF} \times 100 \times 100}{\text{a} \times \text{m} \times (100\% - \%\ \text{ẩm}) \times 1000} \quad (1)$$

here, *y* is the OD value of the analysed sample; *a* and *b* are the coefficients of the gallic acid standard curve equation (10-70 g/ml); *V* is the extract volume (ml); *DF* is the dilution; *m* is the mass of the sample (g).

Determination of vitamin C content: The vitamin C content was determined using the method of K. Pathy (2018) [9]. The sample, post-crushing, was weighed (0.1 g) into a 100 ml volumetric flask, to which 2 drops of 2% HCl and distilled water up to the mark were added. After thorough mixing, the sample was filtered to obtain the extract. For analysis, 10 ml of this extract was taken, mixed with 2 drops of a 0.5% starch-saturated solution, and titrated with 0.01 N iodine solution until a persistent blue coloration was observed for 30 seconds. Vitamin C content is calculated using Eq. (2) and expressed as mg/100 g of dry matter (mg/100 g dm):

$$X\ (mg/100\ g\ dm) = \frac{V \times V_1 \times 0.88 \times 100}{V_2 \times m} \quad (2)$$

in which *V* is the volume of 0.01 N I_2 solution used for titration (ml); V_1 is the volume of test sample solution (ml); V_2 is the volume of sample solution taken for determination (ml); 0.88 is the mass of vitamin C (g) corresponding to 1 ml of 0.01 N I_2 solution.

Determination of microbial count: Initially, one gram of the sample was blended with 9 ml of 0.85% sterile saline. Subsequently, the sample underwent further dilution to achieve the appropriate density. Next, 1 ml of the diluted sample was evenly spread over the surface of a pre-prepared medium plate, where potato dextrose agar (PDA) was used for measuring total yeast and mould, and PCA for total aerobic bacteria. After allowing 15 minutes for stabilisation at room temperature, the Petri dishes were inverted and incubated for 72 hours at 30°C in an incubator (IN110, Memmert, Germany). The microbial density was expressed in log CFU/g. This method aligns with the approach outlined by V. Santhirasegaram, et al. (2013) [10].

2.5. Sensory evaluation

The sensory evaluation involved a panel assessing the organoleptic qualities of the samples, including texture, taste, colour, and overall preference. A 7-point scale was used, with 1 indicating least favourite and 7 most favourite. The sensory panel consisted of 20 individuals, aged between 18-25 years. Between sample tastings, panellists cleansed their palates with odourless water. Each 20-g sample was presented in a white porcelain dish, labelled with a random 3-digit code. The evaluation method was adapted from de P.H.M.D. Sousa, et al. (2010) [6], with minor modifications.

2.6. Degradation kinetic

The degradation kinetics of vitamin C and polyphenols in acerola agar during storage follow a first-order model, as demonstrated by Eq. (3):

$$\ln C = \ln C_o - kt \quad (3)$$

where C is the content of vitamin C or polyphenols after storage time *t*; C_o is the content of vitamin C or polyphenols before storage (i.e., sample after thermal treatment); *k* is the reaction rate constant (day^{-1}) calculated from the base coefficient of the method C/C_o process according to storage time t (days). The half-life ($t_{1/2}$), representing the time for a 50% reduction in content, is determined by Eq. (4):

$t_{1/2} = \ln(2)/k$

(4)

The time required for a 90% reduction in content (D) is calculated using Eq. (5) and Eq. (6):

$D = \ln(10)/k$

(5)

$D = D_o\ 10^{-T/z}$

(6)

where T is the storage temperature (℃); z is the temperature required to reduce one log of price value D (℃); D_o is the value of D when at T=0℃.

The relationship between loss of vitamin C, polyphenols, and temperature during storage follows the Arrhenius model, as indicted in Eq. (7):

$k = Ae^{-Ea/RT}$

(7)

where A is constant; E_a (kJ/mol) is the activation energy (minimum energy required for a chemical reaction to occur) and calculated based on the base coefficient obtained from the straight line of the Eq. (7); R is the universal gas constant (8.314 J/mol K); T is the absolute storage temperature (°K).

The kinetic models (Eqs. (3)-(7)) are based on the report by M.A.J.S.V. Boekel (2008) [11].

The predicted shelf life for vitamin C and polyphenols is determined using Eq. (8), as referenced in M.M.I.A. Zubaidy, et al. (2007) [12]:

$$Ex = e^{-[\frac{S}{T}+I-\ln\left(-\ln\left(\frac{p\%}{100}\right)\right)]}$$

(8)

where *Ex* is the shelf life of the product (days); *S* and *I* are the original coefficients and constants obtained from the Arrhenius equation; *T* is the absolute storage temperature (°K); *p%* is the residual percentage of vitamin C and polyphenols after storage.

2.7. Statistical analysis

The study employed one-way analysis of variance (ANOVA) and the least significant difference (LSD) test for statistical analysis, using JMP software (version

13.0). Excel 2019 was utilised for data calculation, graph plotting, and verification of statistical results.

3. Results and discussion

3.1. Effect of pasteurisation conditions

Microbial count: Thermal treatment in fruit and vegetable processing is crucial for controlling microbiological safety. However, heat treatment can also negatively affect the chemical composition, particularly the content of healthy components such as vitamins. Despite this, pasteurisation is still one of the most effective methods of product preservation, ensuring long shelf life and safety [13]. It is also an easy method to apply with low investment costs. In this experiment, the effects of different pasteurisation regimes on the microbial count and physicochemical properties of acerola jelly were evaluated, as shown in Tables 2 and 3.

Table 2. Effect of pasteurisation regimes on microbial count in acerola jelly.

Time (min)	Temperature (ºC)	Acerobic count (CFU/g)	Yeast and mould (CFU/g)
Before pasteurisation		$2x10^1$	-
5	80	-	-
	85	-	-
	90	-	-
10	80	-	-
	85	-	-
	90	-	-

-: not detected.

Table 3. Effect of pasteurisation regimes on physicochemical properties of acerola jelly.

Time (minute)	Temperature (°C)	TSS (%)	TA (%)	pH	TPC (mg/100 g dm)	Vitamin C (mg/100 g dm)
Before pasteurisation		22,83±0,76	0.35±0,05	0.41±0,07	853.12±7.65	947.56±10.22
5	80	$22,70^{a}$±0,10	$0,28^{a}$±0,01	$4,22^{b}$±0,03	$427,38^{a}$±20,13	$394,13^{a}$±0,77
	85	$22,97^{a}$±0,32	$0,24^{c}$±0,01	$4,34^{a}$±0,05	$412,5^{a}$±11,65	$369,7^{b}$±6,06
	90	$22,93^{a}$±0,06	$0,24^{c}$±0,01	$4,36^{a}$±0,06	$379,39^{ab}$±29,37	$276,31^{e}$±2,20
10	80	$22,87^{a}$±0,12	$0,26^{b}$±0,01	$4,29^{ab}$±0,06	$407,29^{ab}$±7,18	$353,03^{c}$±4,30
	85	$22,93^{a}$±0,21	$0,29^{a}$±0,01	$4,35^{a}$±0,06	$384,23^{ab}$±25,77	$290,76^{d}$±4,46
	90	$22,90^{a}$±0,10	$0,24^{c}$±0,01	$4,35^{a}$±0,04	$353,35^{b}$±28,48	$251,99^{f}$±2,49

The results were expressed as mean ± standard deviation. In the same column, values denoted with different superscript letters had statistically different significance ($p<0.05$).

The microbial analysis showed that no aerobic bacteria or mould yeast were detected in any pasteurisation regime. The acerola jelly, with a pH ranging from 4.2 to 4.4, exhibited acidic characteristics that reduced the heat resistance of microorganisms, facilitating their destruction after heat treatment [5]. Additionally, high temperatures can rupture cellular membranes and denature nucleic acids and proteins, effectively eliminating spoilage microorganisms [10]. Previous research has indicated that aerobic bacteria, yeast, and mould were not detected in mango juice treated at 90℃ for 15 seconds, in blended orange and carrot juice at 98℃ for 21 seconds, and in pineapple juice at 80℃ for 15 minutes [10, 14, 15].

3.2. Physicochemical properties

Generally, all heated jelly samples maintained TSS values of approximately 23%, TA from 0.24 to 0.29%, and pH levels between 4.2 and 4.4 (Table 3). However, the content of biological compounds, such as vitamin C and polyphenols, varied significantly among the samples ($p<0.05$). The concentration of these compounds decreased with increasing temperatures and extended treatment times. Notably, the vitamin C content was observed to be 394.13 mg/100 g dm at 80ºC, 369.97 mg/100 g dm at 85ºC, and 276.31 mg/100 g dm at 90ºC, all for a heating duration of 5 minutes. This trend is consistent with previous studies on acerola-based products [3-5, 13, 16].

The increase in temperature from 85 to 95ºC led to an escalation in the degradation of vitamin C in acerola juice, from 46.75 to 50.65% [5]. Similarly, acerola powder dried at 130ºC showed a recovery yield of vitamin C and polyphenols of 43.52 and 49.54%, respectively, which were higher than the yields at 170ºC (31.30 and 30.66%, respectively) [3]. Another study on acerola jam indicated that reducing the heating time enhanced the retention of vitamin C, increasing the percentage remaining from 71.99 to 93.68% [4]. Research on other fruits has also noted that heat-sensitive compounds, such as vitamin C and polyphenols, degrade rapidly at high temperatures over time [13, 16].

3.3. Sensory evaluation

Regarding colour, acerola contains compounds like cyanidin 3-O-rhamnoside and pelargonidin 3-O-rhamnoside (anthocyanins), and neochrome, lutein, and zeaxanthin

(carotenoids), which contribute to the ripe fruit's hue [2]. Although these pigments are susceptible to degradation during thermal processing, the colour of acerola jelly varied only slightly across different pasteurisation regimes. All samples presented an attractive orange-yellow colour, with the highest score (5.70/7 points) observed for the sample treated at 85°C for 10 minutes, and the lowest (4.80/7 points) for the one treated at 85°C for 5 minutes (Table 4). Additionally, pasteurisation conditions appeared to have minimal impact on consumer preferences for texture, with sensory scores ranging from 4.85 to 5.55 out of 7 points.

Table 4. Effect of pasteurisation temperature and time on sensory quality of acerola jelly.

Time (minute)	Temperature (°C)	Colour	Texture	Flavour	Overall liking
5	80	5.45^{ab}±0.94	5.25^{a}±0.90	5.60^{a}±1.10	5.15^{bc}±0.88
	85	4.80^{b}±1.24	4.85^{ab}±1.63	5.10^{ab}±1.25	5.25^{bc}±1.02
	90	5.15^{ab}±1.27	5.35^{a}±1.14	4.70^{b}±0.98	4.90^{c}±0.97
10	80	5.45^{ab}±0.89	5.45^{a}±1.23	5.10^{ab}±1.29	5.15^{ac}±1.35
	85	5.70^{a}±1.03	5.40^{a} ±1.43	5.50^{a}±0.95	5.95^{a}±0.76
	90	5.40^{ab}±1.14	5.55^{a}±0.89	5.35^{ab}±1.14	5.55^{ab}±0.94

The results were expressed as mean ± standard deviation. In the same column, values denoted with different superscript letters had statistically different significance ($p<0.05$).

Most panellists noted that the acerola jelly had a balanced sweet and sour taste, consistent across the samples. This taste profile is primarily influenced by the acid and sugar content (dissolved solids), with little variation in TA, TSS, and pH between the jelly samples, as shown in Table 3. Furthermore, the aroma of acerola was perceptible in the product, although differences in odour intensity were not pronounced between the samples. Volatile compounds such as esters, terpenoids, aldehydes, ketones, alcohols, and acids have been identified as key contributors to acerola's characteristic aroma [17]. The jelly's structure might have aided in retaining these aromatics during processing.

Given the analysed results, the pasteurisation condition of 80°C for 5 minutes was chosen as optimal. This regime ensured that the content of spoilage microorganisms was within safe limits, while maintaining good organoleptic quality and a higher content of vitamin C and polyphenols compared to other samples.

The results were expressed as mean ± standard deviation. In the same column, values denoted with different superscript letters had statistically different significance ($p<0.05$).

3.4. Effect of storage conditions

Kinetic modelling of vitamin C and polyphenol degradation: To ascertain the shelf life of food products, the conventional approach involves monitoring changes in product quality during storage. Nevertheless, heat-treated products often have extended life cycles, rendering the determination of their shelf life time-consuming and thus challenging for commercialisation. To address this issue, the accelerated method has been employed. The first-order model and the Arrhenius model are extensively used to assess the impact of temperature on the kinetics of chemical and biological reaction mechanisms in food. These models are instrumental in predicting optimal preservation conditions and minimising quality losses during food storage [18].

During storage, the degradation of vitamin C and polyphenols in acerola jelly was modelled using the first-order and Arrhenius models (Fig. 1). The negative sign preceding the slope of the first-order equation indicates an inverse relationship between time and the concentration of biological compounds. An increase in temperature results in a heightened degradation rate of antioxidant compounds. For example, as the temperature rose from 8°C to 40°C, the rate constant (k) for vitamin C increased from 0.0141 to 0.0446 day^{-1}, leading to a significant reduction in the half-life ($t_{1/2}$) from 49.16 to 15.51 days. This pattern was also observed in previous studies. For instance, in kiwifruit puree, an increase in storage temperature from 5 to 45°C resulted in the k value for polyphenols rising from 1.59 to 6.54 x 10^{-3} $hour^{-1}$, while $t_{1/2}$ decreased from 18.19 to 4.42 days [19]. Similarly, with the storage temperature of lingonberry jam rising from 4 to 25°C, the k value increased from 0.87 to 1.42 day^{-1}, but $t_{1/2}$ decreased from 256 to 157 days [20].

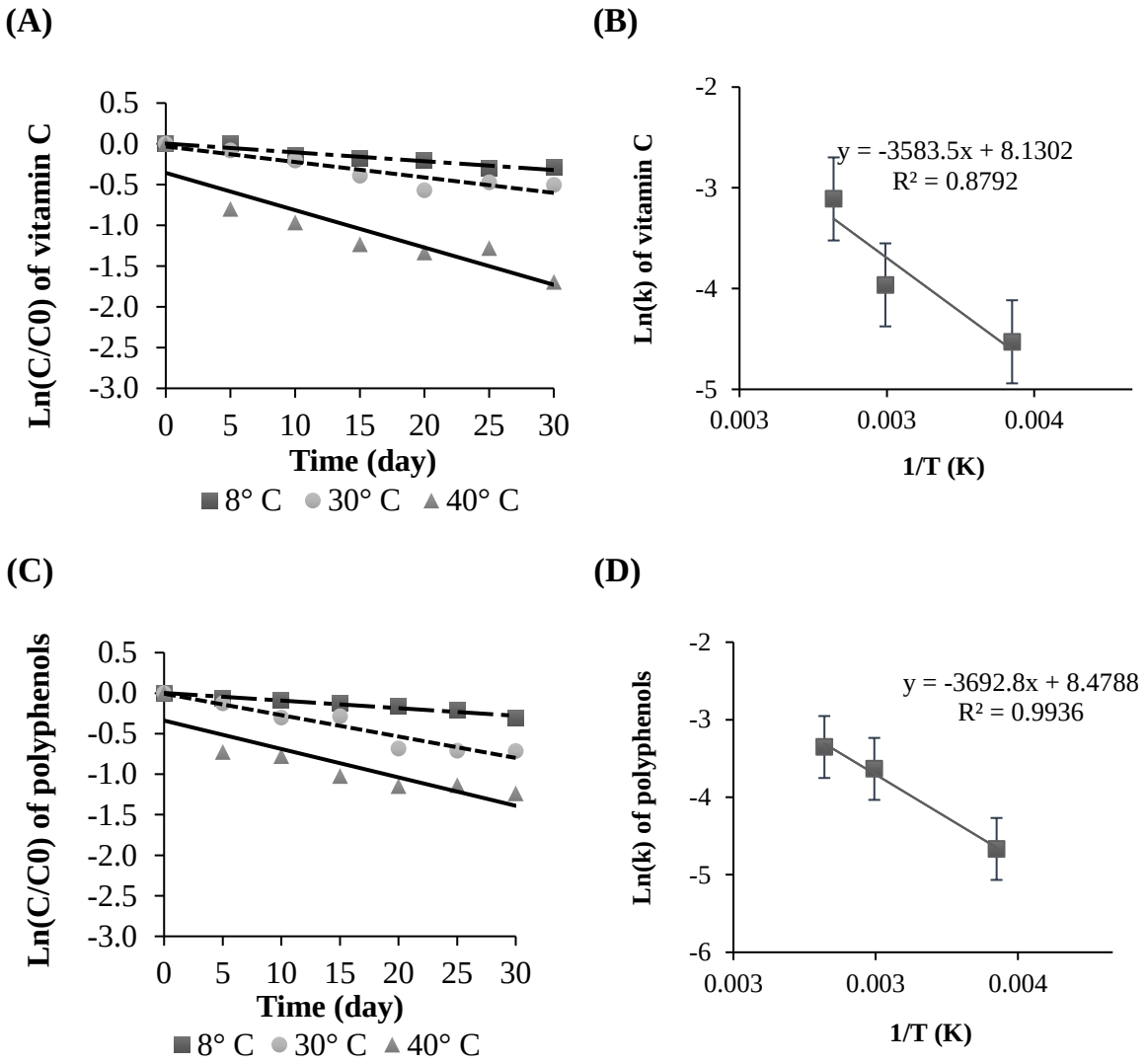

Fig. 1. (A) First order model plot and (B) Arrhenius model plot for degradation of vitamin C; first order model plot and (C) Arrhenius model plot (D) for degradation of TPC in acerola jelly under various storage temperatures.

The adverse impact of temperature on the stability of vitamin C and polyphenols in acerola jelly was further corroborated through the D value, which significantly diminished at higher temperatures. Specifically, the D value for polyphenols was 244.96 days at 8-10°C, 87.22 days at room temperature, and 65.79 days at 40°C. The temperature rise likely accelerated undesirable reactions such as oxidation and non-enzymatic browning, contributing to the degradation of vitamin C and polyphenols [20, 21].

As presented in Table 5, the activation energy (Ea) of vitamin C (27.69 kJ/mol) was lower than that of polyphenols (30.70 kJ/mol), while the z value of vitamin C (87.72^{o}C) was greater than that of polyphenols (54.64^{o}C), indicating that polyphenols in acerola jelly were more temperature-sensitive. The lower z and higher E_a values suggest a more pronounced temperature dependence of the reactions [11]. In other research, the activation energy of vitamin C in orange and pear juice was recorded as 44.81 and 55.44 kJ/mol, respectively [22]. Meanwhile, the Ea value for polyphenols was reported as 3.5 kJ/mol in cherry jam [21], and 28.15 kJ/mol in kiwi puree [19].

Table 5. Degradation parameters of vitamin C and polyphenols of acerola jelly under various storage temperatures.

Temperature (°C)	**k (day^{-1})**	**$t_{1/2}$ (day)**	***R^2**	**D (day)**	**E_a (KJ/mol)**	****R^2**	**Z (℃)**	*****R^2**
Vitamin C								
8-10	0.0108	64.18	0.95	213.20				
29-31	0.019	36.48	0.84	121.19	29.79	0.88	87.72	0.89
40	0.0446	15.54	0.79	51.63				
TPC								
4-6	0.0094	73.74	0.96	244.96				
29-31	0.0264	26.26	0.91	87.22	30.70	0.99	54.64	0.99
40	0.035	19.80	0.79	65.79				

The coefficient obtains from *: first order model; **: arrhenius model; ***: ball model.

3.5. Shelf-life prediction of vitamin C and polyphenol

In this study, the recovery yield of vitamin C in acerola jelly was found to be 75.05, 60.51, and 18.41% after 30 days of storage at 8-10^{o}C, room temperature, and 40^{o}C, respectively. Similarly, the remaining percentages of TPC under the same storage conditions were 73.05, 48.95, and 29.04%, respectively. These parameters are likely to continue degrading with prolonged storage time. The predictive equations for the degradation of vitamin C and polyphenols are presented in Table 6.

Table 6. Change in TSS, pH, and TA of acerola jelly over time at various storage temperatures.

Temperature	**Storage time (day)**						
(℃)	***0***	***5***	***10***	***15***	***20***	***25***	***30***
TSS (%)							

8-10	23.57±0.51	23.57±0.64	23.2±0.40	23.17±0.25	23.53±0.70	23.53±0.12	23.4±0.53
29-31	23.57±0.14	23.13±0.15	23.4±0.20	23.27±0.12	23.13±0.31	23.87±0.12	23.47±0.7
40	23.57±0.05	23.2±0.00	23.8±0.53	23.87±0.58	23.93±0.46	23.53±0.31	23.67±0.12
pH							
8-10	4.07±0.51	4.08±0.13	3.91±0.03	3.92±0.05	3.92±0.05	3.97±0.03	3.97±0.04
29-31	4.07±0.14	3.93±0.04	4.04±0.17	4.08±0.29	4.08±0.29	3.95±0.09	3.97±0.03
40	4.07±0.05	4.04±0.29	3.88±0.05	4.01±0.17	4.01±0.17	3.96±0.03	4.02±0.12
TA (%)							
8-10	0.28±0.51	0.36 ± 0.06	0.29±0.01	0.28±0.02	0.28±0.01	0.28±0.02	0.29±0.00
29-31	0.28±0.14	0.35 ± 0.00	0.29±0.01	0.28±0.02	0.30±0.02	0.3±0.02	0.28±0.01
40	0.28±0.05	0.35 ± 0.00	0.30±0.02	0.30±0.01	0.32±0.00	0.3±0.01	0.31±0.01

The results were expressed as mean ± standard deviation.

The decline of these compounds during storage has been noted in various acerola products. For instance, acerola jam, after a month, retained 55.98% of its polyphenol content and 23.98% of its vitamin C content [4]. A study examining the impact of storage temperature on fresh acerola fruits found that after three days of storage at room temperature, the content of vitamin C and polyphenols was reduced to 40% and 70% respectively, while at colder temperatures, these figures were 15 and 30% respectively [3]. These findings indicate that lower temperatures are more effective in preserving antioxidant compounds in acerola products and suggest that vitamin C is less affected than polyphenols during storage.

Research by N.J. Wurlitzer, et al. (2019) [23] observed no significant changes in the content of vitamin C and polyphenols in blended acerola juice over 180 days of storage at 5ºC. Conversely, another study on acerola juice [5] reported that vitamin C was lost not only during pasteurisation but also throughout the storage period. After six weeks of storage at room temperature, the loss rate of vitamin C in acerola juice was 37.4%. This study also suggested that the rate of vitamin C degradation decreases over time, possibly due to the gradual reduction in the amount of dissolved oxygen inside the packaging and the intrinsic properties of the product, leading to fewer oxidation reactions [24].

3.6. Microbial count, TSS, TA, and pH

The results displayed in Table 7 indicate that after 30 days of storage at 8-10°C and 29-31°C, the acerola jelly samples did not exhibit growth of aerobic bacteria and mould yeast.

Table 7. Microbial count in acerola jelly before and after storage.

Sample	Temperature (°C)	Acerobic count (CFU/g)	Yeast and mould (CFU/g)
Before	8-10	-	-
	29-31	-	-
After 30 days	8-10	-	-
	29-31	-	-

-: not detected.

Over the course of 30 days of storage, this study observed fluctuations in the physicochemical properties of acerola jelly at various temperatures (Table 8). Generally, the acerola jelly maintained a TSS range of 23-24%, a pH of 3.9-4.1, and a TA of 0.28-0.35%. Similarly, in guava juice, TSS, pH, and TA remained relatively unchanged over 240 days of storage at 10°C [24], with TSS varying between 23% and 24%, pH between 3.70 and 3.8, and TA between 0.22% and 0.25%. Another study on orange, pear, and grape juices [22] suggested that pH and TSS experienced minor modifications when stored at 4°C, 25°C, and 37°C. Research by P.H.M.D. Sousa, et al. (2010) [6] noted that after 180 days of storage at 4°C, grapefruit juice retained a pH of 3.0 and a TSS of 10%, consistent with its initial values. Additionally, after 60 days of storage at 26°C, pasteurised pineapple juice exhibited a TSS range of 15.5% to 16.0% and a pH of approximately 4.0, while TA decreased slightly [15].

Table 8. Change in TSS, pH, and TA of acerola jelly over time at various storage temperatures.

Temperature (℃)	Storage time (day)						
	0	***5***	***10***	***15***	***20***	***25***	***30***
TSS (%)							
8-10	23.57±0.51	23.57±0.64	23.2±0.40	23.17±0.25	23.53±0.70	23.53±0.12	23.4±0.53
29-31	23.57±0.14	23.13±0.15	23.4±0.20	23.27±0.12	23.13±0.31	23.87±0.12	23.47±0.7
40	23.57±0.05	23.2±0.00	23.8±0.53	23.87±0.58	23.93±0.46	23.53±0.31	23.67±0.12
pH							

8-10	4.07±0.51	4.08±0.13	3.91±0.03	3.92±0.05	3.92±0.05	3.97±0.03	3.97±0.04
29-31	4.07±0.14	3.93±0.04	4.04±0.17	4.08±0.29	4.08±0.29	3.95±0.09	3.97±0.03
40	4.07±0.05	4.04±0.29	3.88±0.05	4.01±0.17	4.01±0.17	3.96±0.03	4.02±0.12
TA (%)							
8-10	0.28±0.51	0.36±0.06	0.29±0.01	0.28±0.02	0.28±0.01	0.28±0.02	0.29±0.00
29-31	0.28±0.14	0.35±0.00	0.29±0.01	0.28±0.02	0.30±0.02	0.3±0.02	0.28±0.01
40	0.28±0.05	0.35±0.00	0.30±0.02	0.30±0.01	0.32±0.00	0.3±0.01	0.31±0.01

The results were expressed as mean ± standard deviation.

4. Conclusions

The various pasteurisation and storage conditions did not significantly alter the TSS, total acids, or pH of acerola jelly. However, temperature and time were identified as key factors influencing the degradation of vitamin C and polyphenols. The longer the heat treatment duration and the higher the processing temperature, the greater the loss of these compounds. The optimal pasteurisation conditions for acerola products were determined to be 80°C for 5 minutes; under these conditions, the product met microbiological safety standards and maintained high sensory quality, along with substantial vitamin C and polyphenol content. To preserve these qualities, it is recommended that the product be stored at a low temperature of 4-6^{o}C. At this temperature, the predicted time for the vitamin C and polyphenol content of the product to decrease by 50% is estimated to be 64.17 days and 73.74 days, respectively.

CRediT author statement

Binh Quang Hoang: Methodology, Formal analysis, Writing, Editing; Uyen Phuong Tran Ho: Material synthesis, Data analysis, Editing; Diep Ngoc Thi Duong: Methodology, Formal analysis, Writing, Editing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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